Millimeter-Wave Antenna Arrays with Beam Steering for 5G Mobile Terminals

Shuai Zhang

Associate Professor in Antennas

Section of Antennas, Propagation and Millimeter-Wave Systems (APMS)
Aalborg University, Denmark

Email: sz@es.aau.dk

Biography:

Shuai Zhang received the B.E. degree from the University of Electronic Science and Technology of China, Chengdu, China, in 2007 and the Ph.D. degree in electromagnetic engineering from the Royal Institute of Technology (KTH), Stockholm, Sweden, in 2013. After his Ph.D. studies, he was a Research Fellow at KTH. In April 2014, he joined Aalborg University, Denmark, where he currently works as Associate Professor. In 2010 and 2011, he was a Visiting Researcher at Lund University, Sweden and at Sony Mobile Communications AB, Sweden, respectively. He was also an external antenna specialist at Bang & Olufsen, Denmark from 2016-2017. He has coauthored over 60 articles in well-reputed international journals and over 15 (US or WO) patents. His research interests include: mobile terminal mmwave antennas, biological effects, CubeSat antennas, UWB wind turbine blade deflection sensing, MIMO antenna systems, and RFID antennas.

Abstract:

As the key technologies in future 5G cellular communication systems, millimeter wave (mmwave) will be applied for 5G mobile handsets. In these systems, beam steerable arrays with high gain have to be utilized at both base stations and user terminals in order to overcome the path loss. In mobile terminals, there is very limited space left for 5G arrays after accommodating 2G, 3G and 4G antenna systems. The only power supply in a cellphone is a small battery, which requires low-loss and low-cost beamforming. Moreover, user's mobility and blockage also rise some more new issues. This presentation will introduce the challenges in mm-wave 5G mobile handsets. As some examples, recent progress of the antenna group at Aalborg University will be introduced in the area of mm-wave beam-steerable antenna arrays and their biological effects for 5G mobile terminals. In the base stations, massive MIMO is widely used in sub 6 GHz and in mmwave in the future. The mutual coupling between array elements is highly preferred to be lower than – 25 dB in consideration of active VSWR and system requirements. Moreover, the decoupling method should also be wideband and without significantly impacting the radiation patterns of array elements. This presentation will introduce a transmission line base method for isolation enhancement. Finally, the new anechoic chamber in Aalborg University will be highlighted.

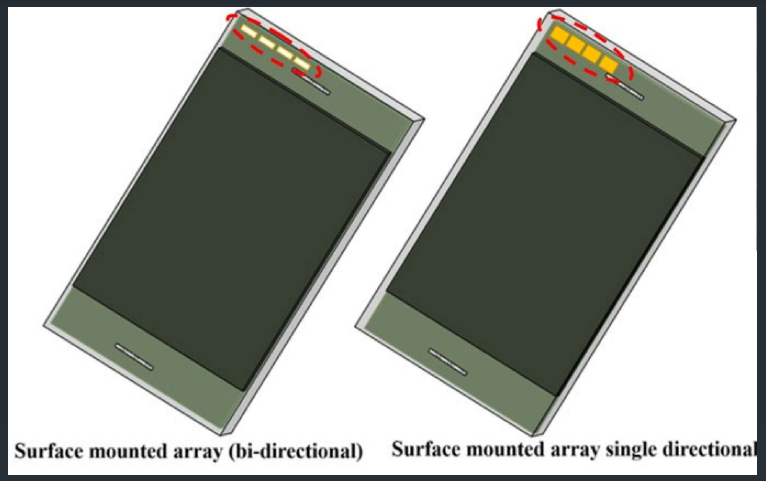
Index Terms:
mmwave antenna array, mobile handset, massive MIMO antenna, base station, mutual coupling, anechoic chamber

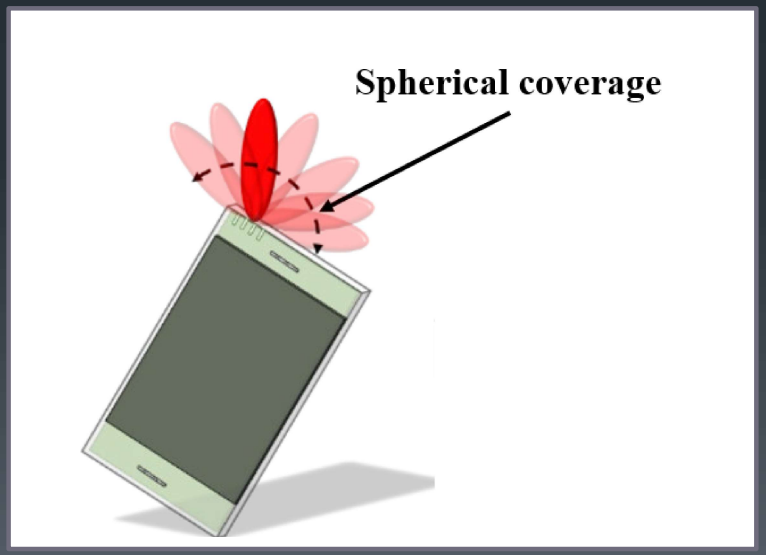
Outlines:

- 1. Introduction
- 2. New challenges in 5G handset antennas
- 3. Design examples
- 4. User effects on mm/cm-wave antenna designs
- 5. Conclusions

1. Introduction:

1. Frequency: 24-43 GHz
2. Number of sub arrays : typ. 2-4
3. Number of array elements: typical. 4-8



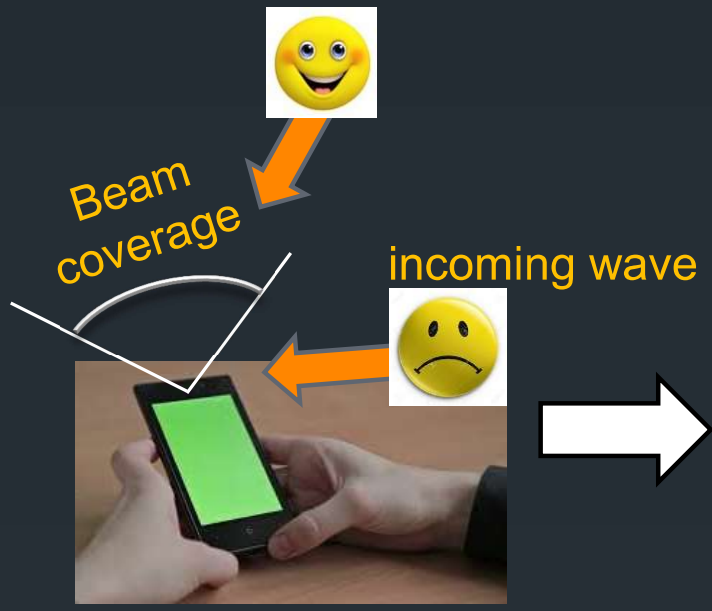


- **More directional beam**
- **Beam steering.**

2. New challenges in 5G handset antennas:

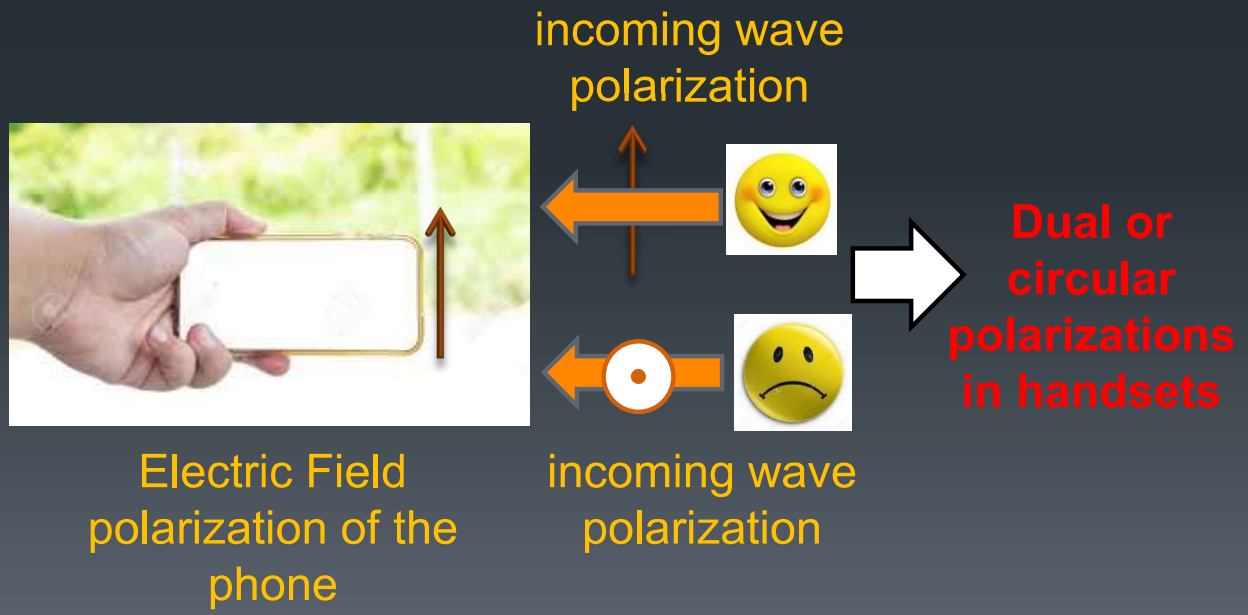
1). Phone mobility

A). Random phone orientation and random incoming wave direction

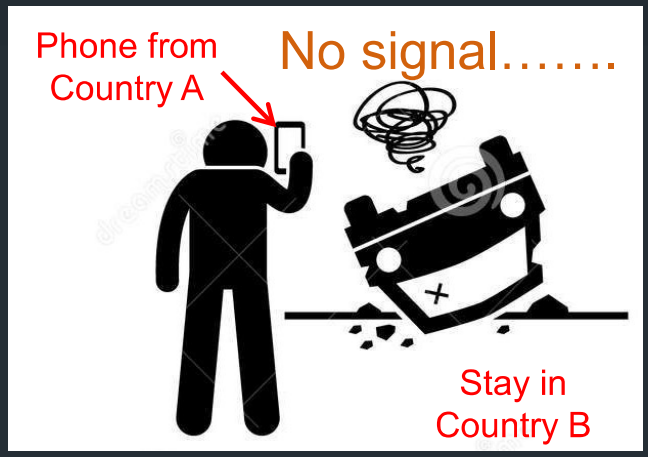


Large beam coverage in handsets

B). Random phone orientation and random incoming wave polarization



C). Different frequency bands in different countries



Handset antenna cover all the bands

2). Integration of antennas in sub 3 GHz and Cmwave frequencies

The inside of a current phone

Where to place 5G antennas?!!

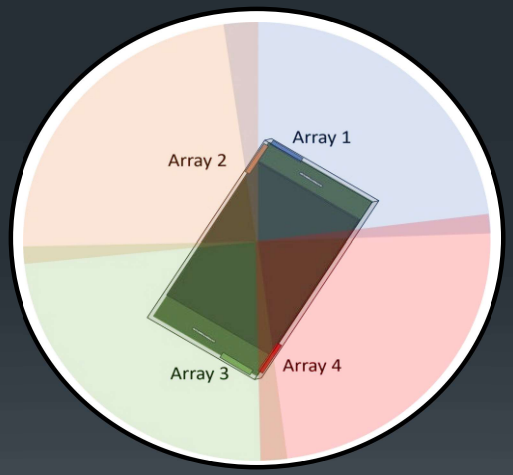
Reuse the antenna location of sub 3GHz for 5G antennas

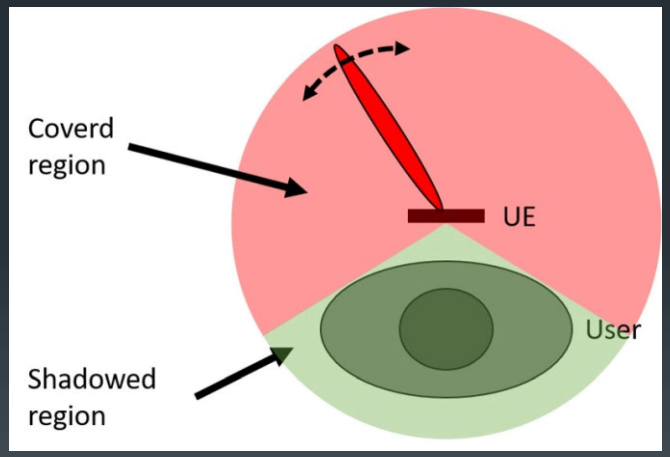
3). High loss of beamforming control

The loss of a phase shifter modules (instead of die) is typiclly from 6-10 dB. Issues of power consumption, and temperature increase.

How to realize beam steering in another way instead of a phased array?

4). User body blockage



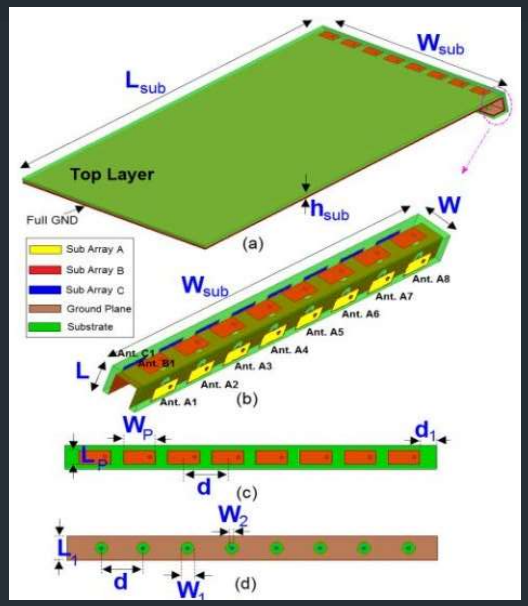


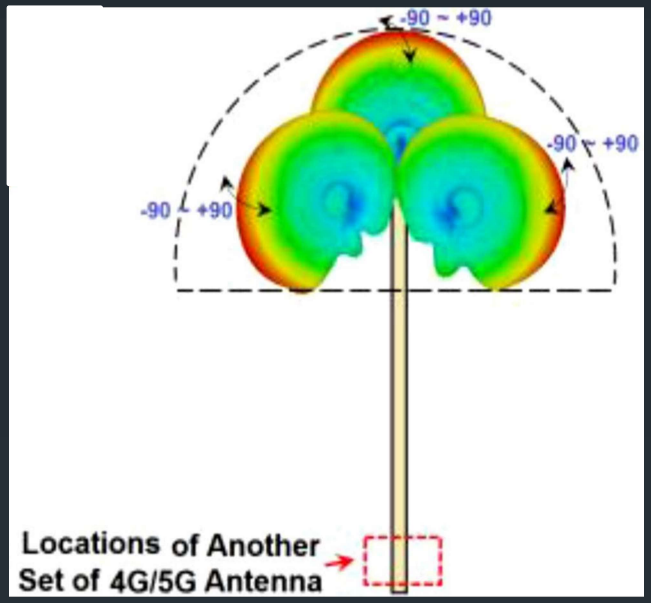
The 5G antennas capable of combatting shadowing

3. Design Examples:

Large spatial coverage

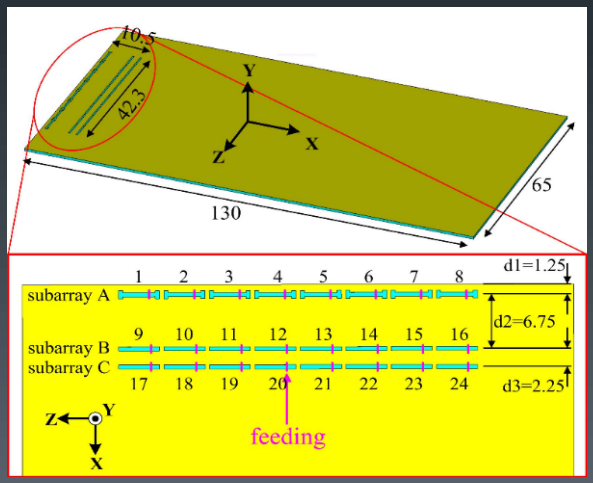
Folded edge

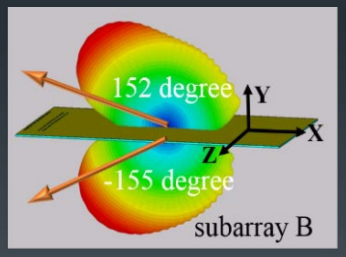


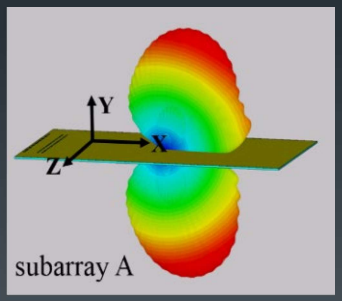


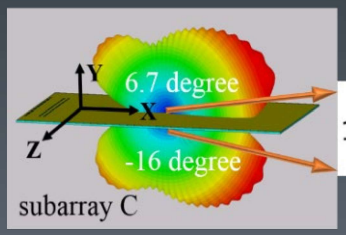
"A switchable 3D-coverage phased array antenna package for 5G mobile terminals"

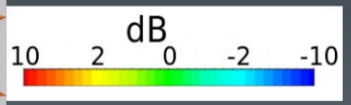
Control surface currents





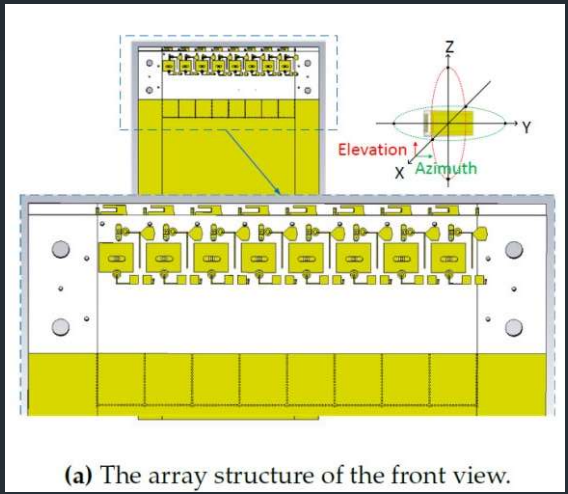






"A planar switchable 3D-coverage Phased array antenna and its user effects for 28 GHz mobile terminal applications."

PIN diode control (27-28 GHz)



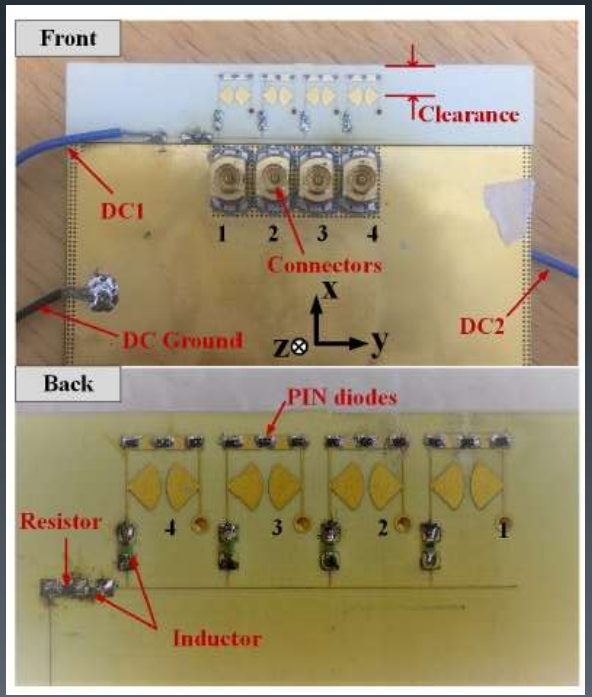
(a) The array structure of the front view.

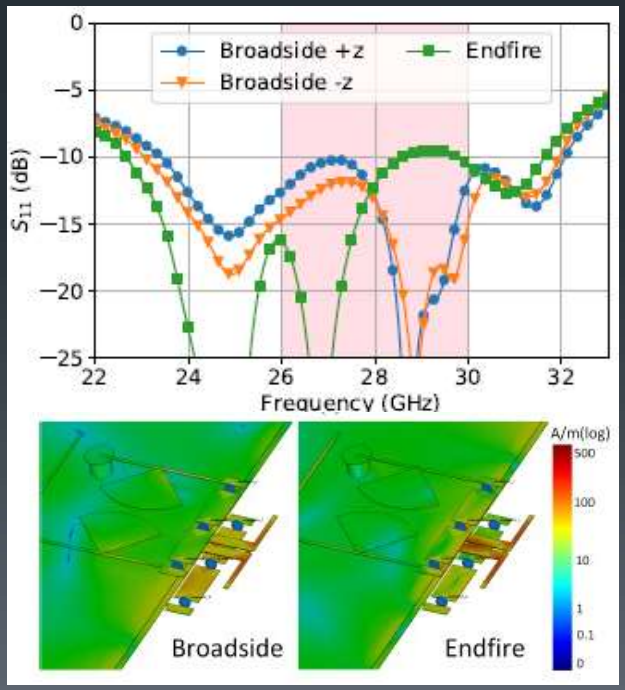

(b) Front view.


(c) Back view.

"3D Radiation Pattern Reconfigurable Phased Array for Transmission Angle Sensing in 5G Mobile Communication"

PIN diode control (26-30 GHz)

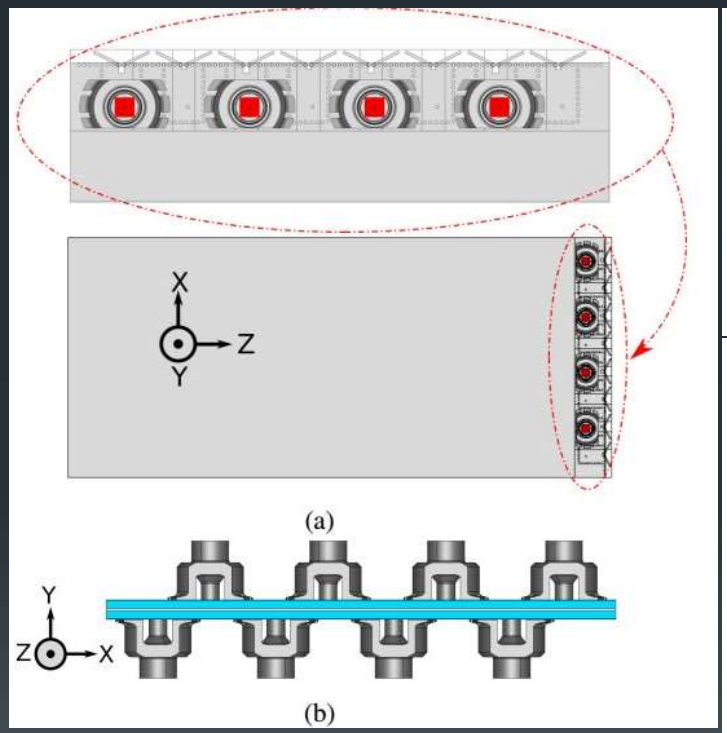


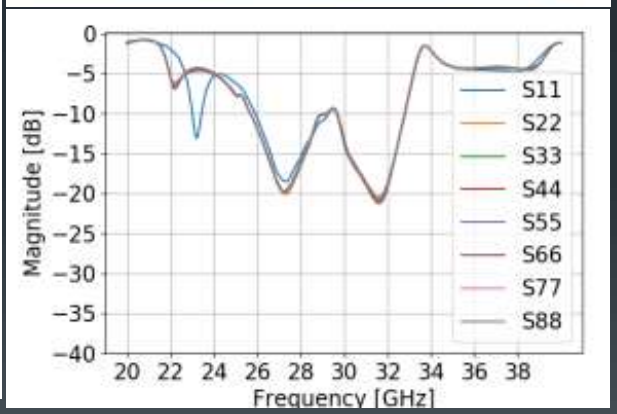


"Radiation-Pattern Reconfigurable Phased Array with PIN Diodes Controlled for 5G Mobile Terminals"

Wideband

Wide bandwidth and large scan angle

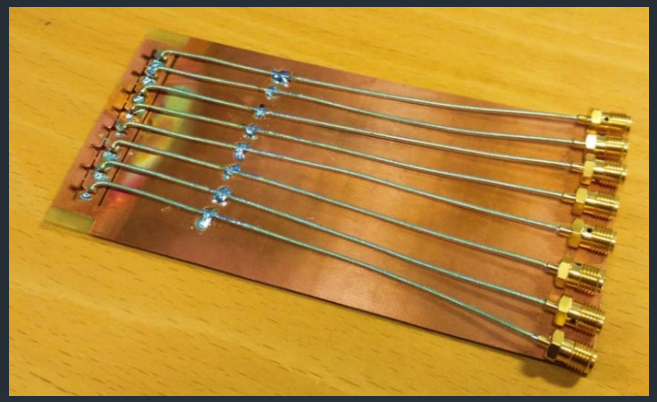




"Compact Quad-Mode Planar Phased Array with Wideband for 5G Mobile Terminals,"

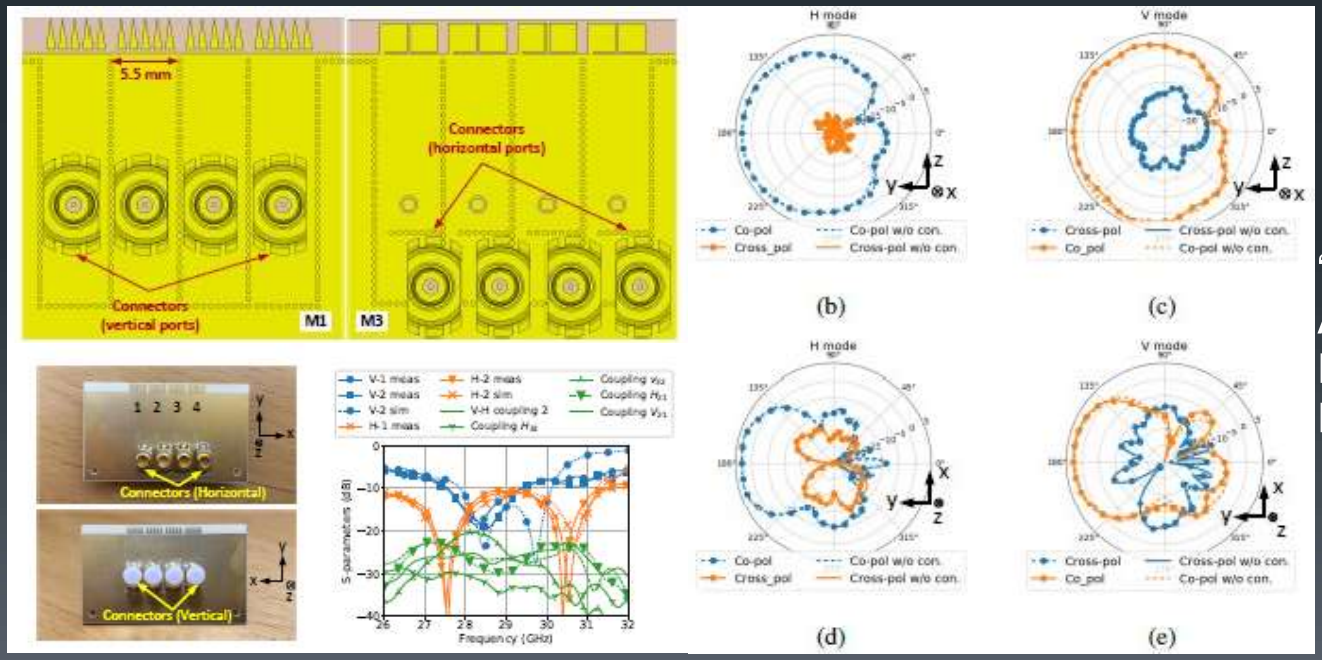
Polarization

Circular polarization



"Substrate-Insensitive Phased Array with Improved Circularly-Polarized Scan Angle for 5G Mobile Terminals"

Dual polarization

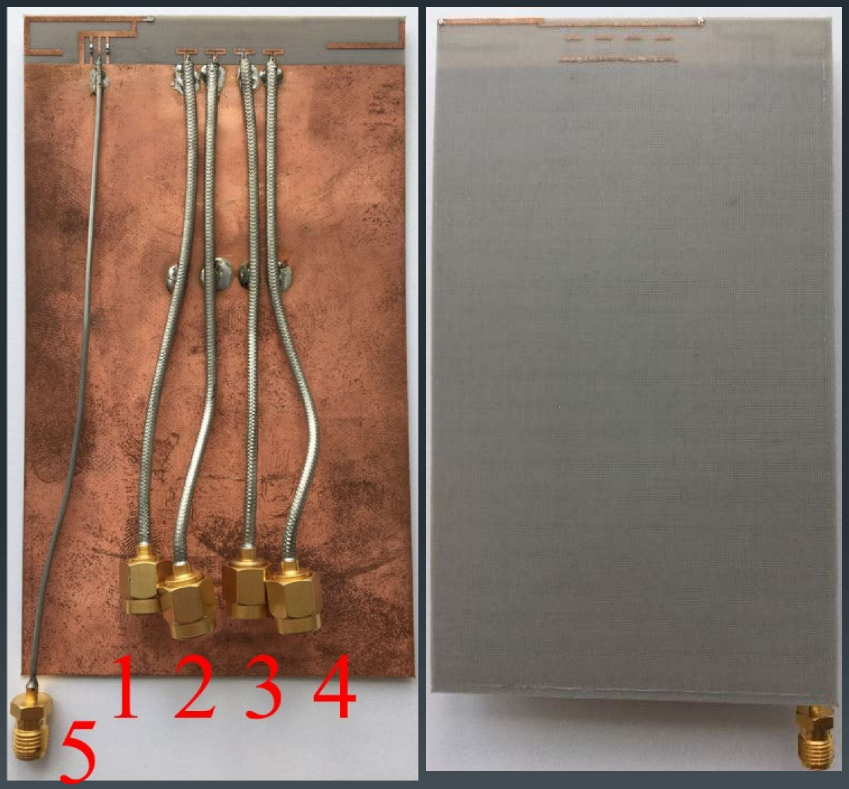


"Dual-Polarized Phased Array with Endfire Radiation for 5G Handset Applications"

Low profile of 1.1 mm and clearance of 2.7 mm

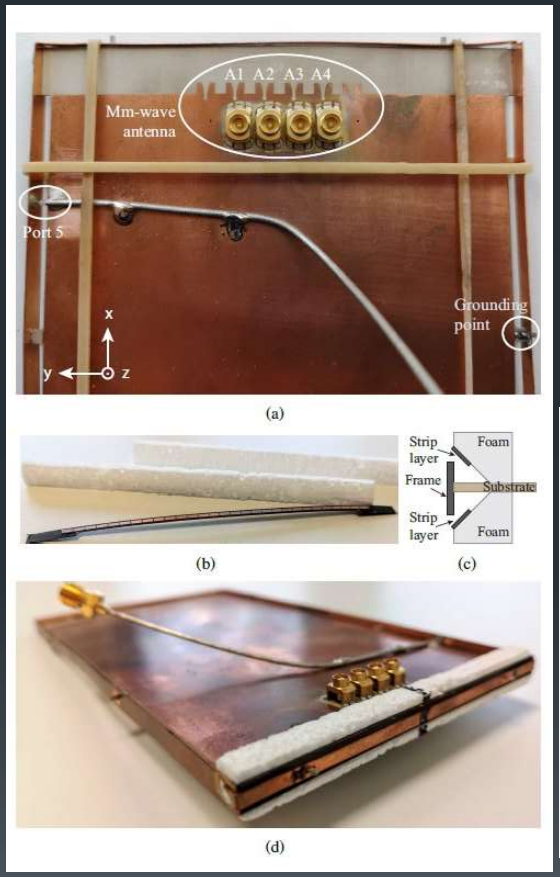
Co-design of sub 3GHz and mmwave antennas

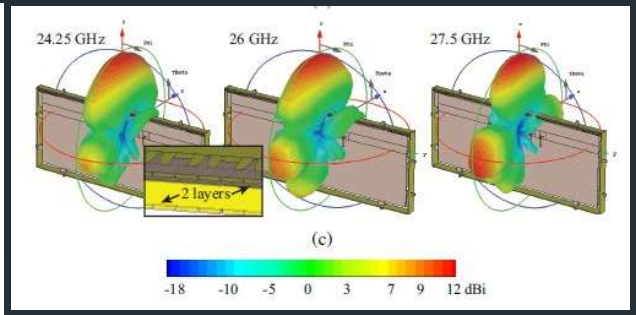
Integration of mmwave and sub 3GHz planar antennas

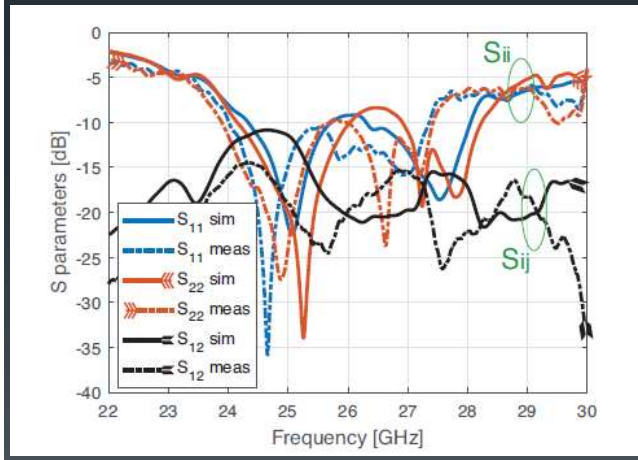


"Integrated Millimeter-Wave Wideband End-Fire 5G Beam Steerable Array and Low-Frequency 4G LTE Antenna in Mobile Terminals."

Integration of mmwave and sub 3GHz bezel antennas



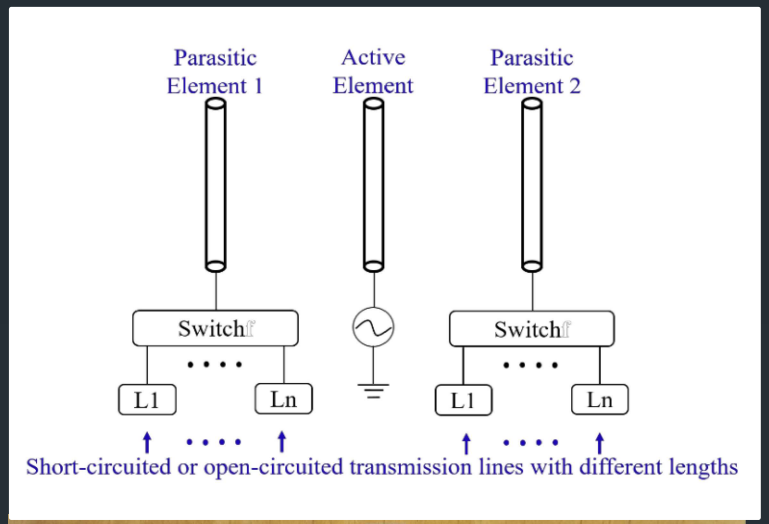


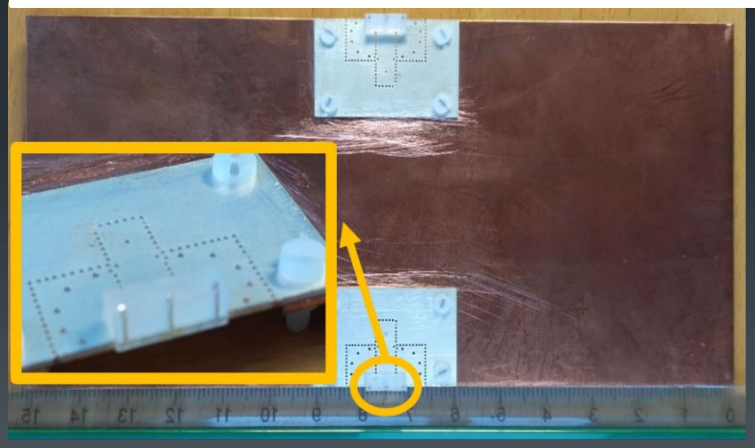


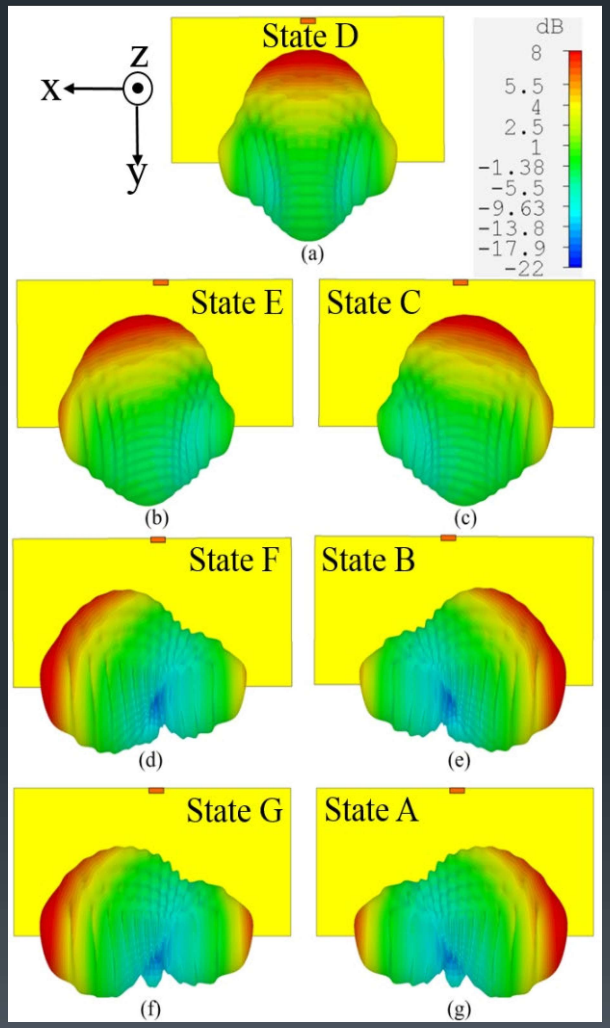
"Reduction of Main Beam-Blockage in an Integrated 5G Array with a Metal-Frame Antenna"

Beam steering array with low loss switch

Compact Beam-Steerable Antenna Array With Two Passive Parasitic Elements







"Compact Beam-Steerable Antenna Array With Two Passive Parasitic Elements for 5G Mobile Terminals at 28 GHz,"

Loss: two switches with 2.8 dB loss cause less than 1.82 dB loss for the whole array. (phase shifters with similar states will lead to at least 6 dB loss.)

Wideband High Gain Beam-Switchable Quasi-Yagi Array for Mobile Devices

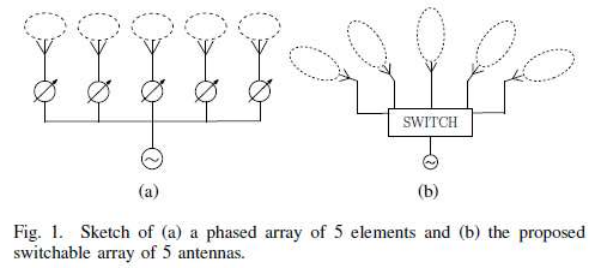
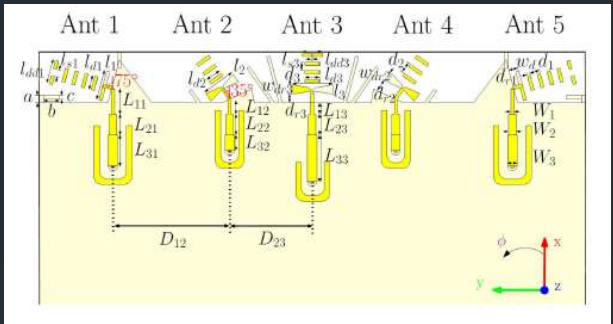
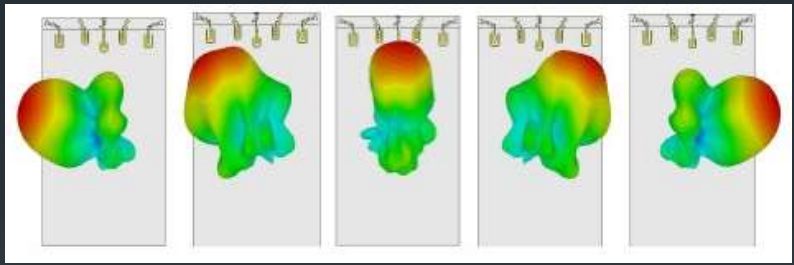


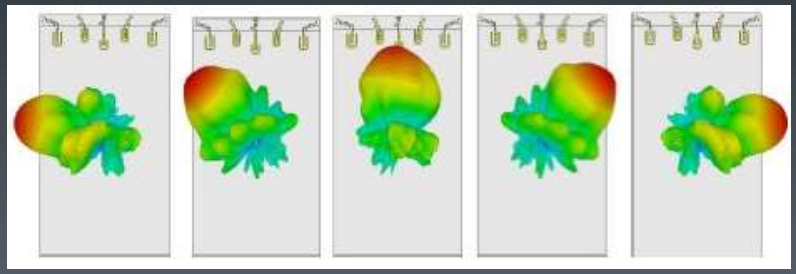
Fig. 1. Sketch of (a) a phased array of 5 elements and (b) the proposed switchable array of 5 antennas.

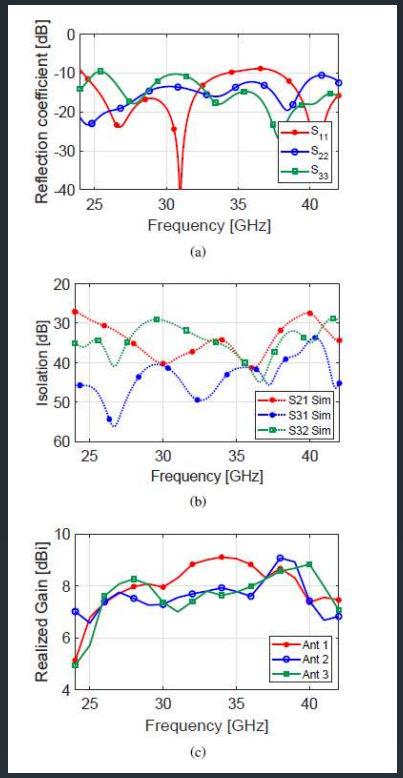


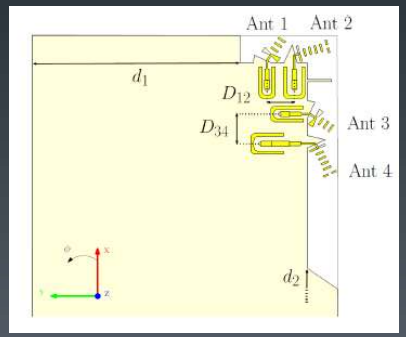
28 GHz

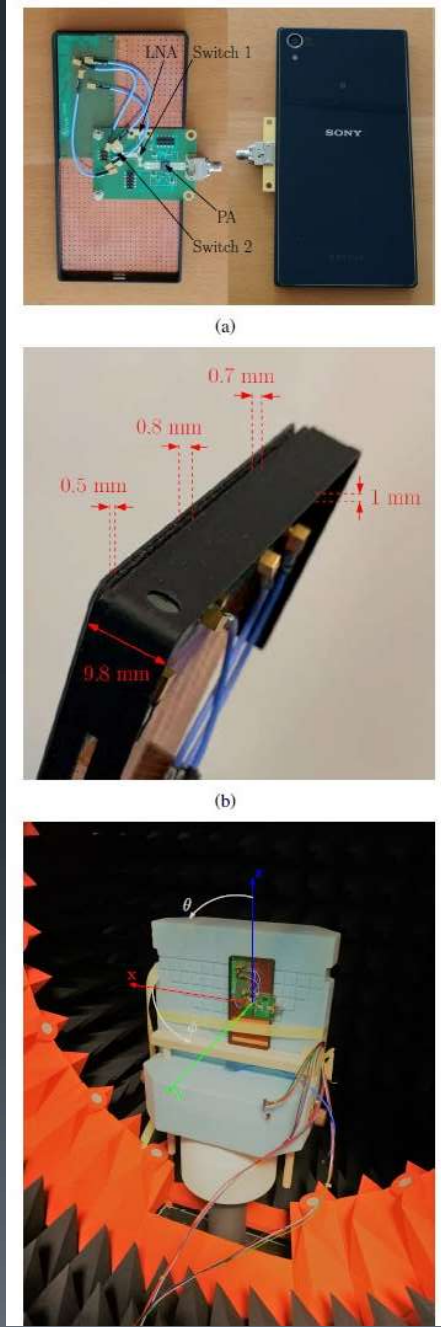


38 GHz





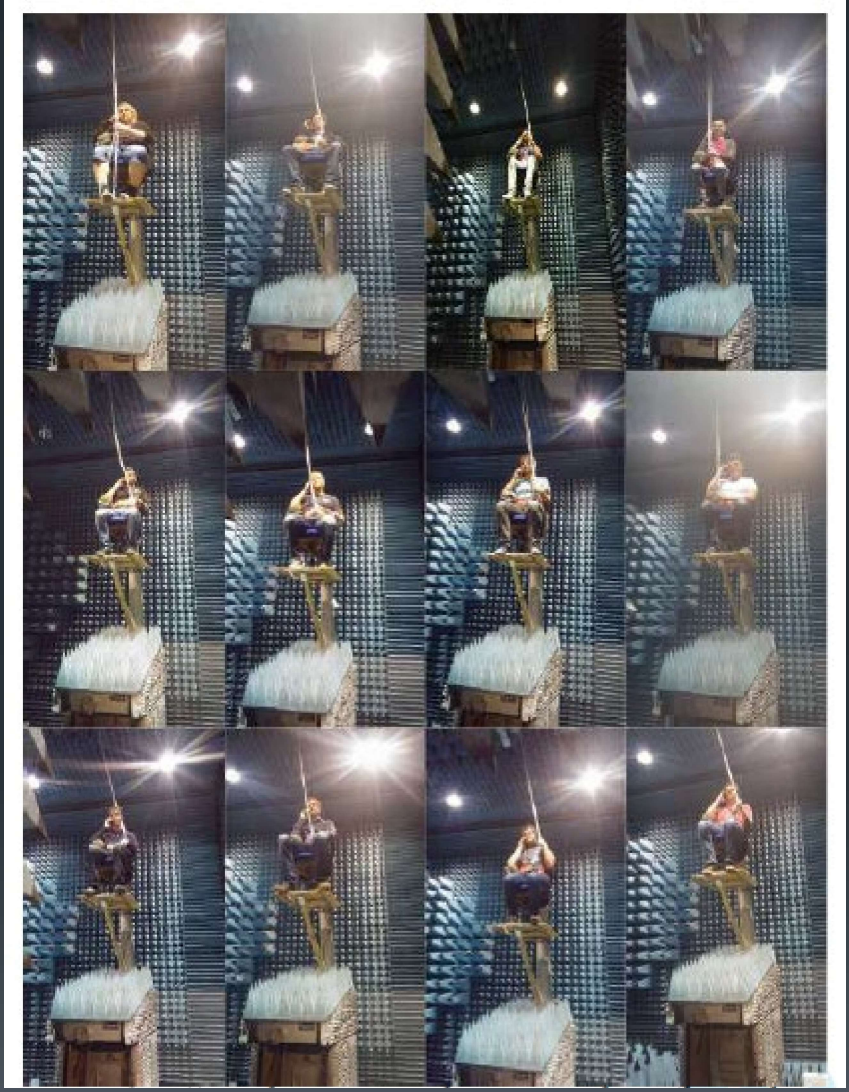




"Wideband Beam-Switchable 28 GHz Quasi-Yagi Array for Mobile Devices"

4. User effects on mm/cm-wave antenna designs

Statistical Investigation



The following issues are studied under **12 users** with the phased array on the top and bottom of the phone:

1.Shadowing variation
2.Body loss variation
3.Coverage efficiency variation

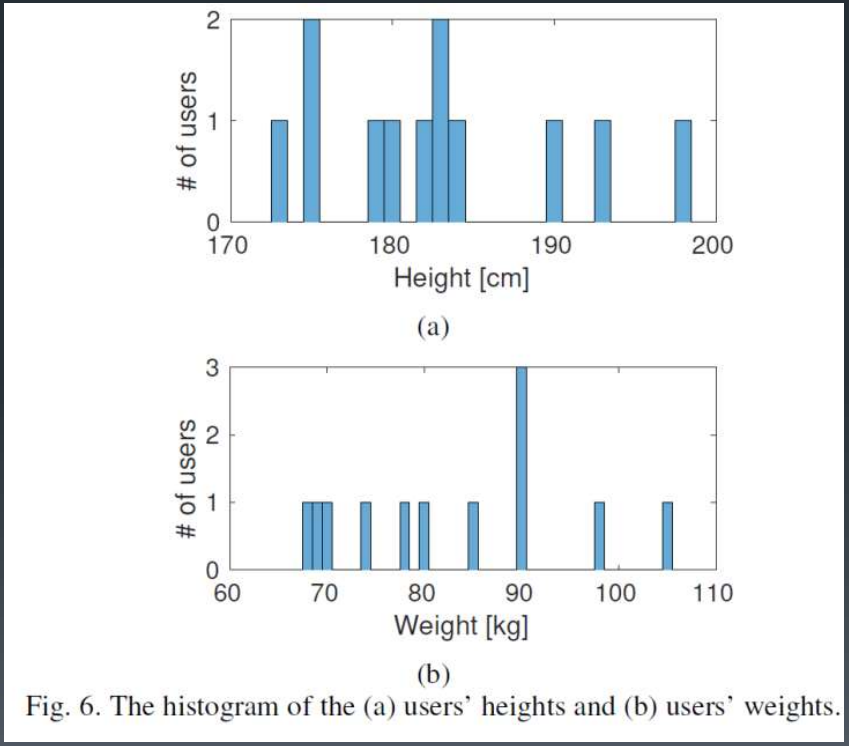
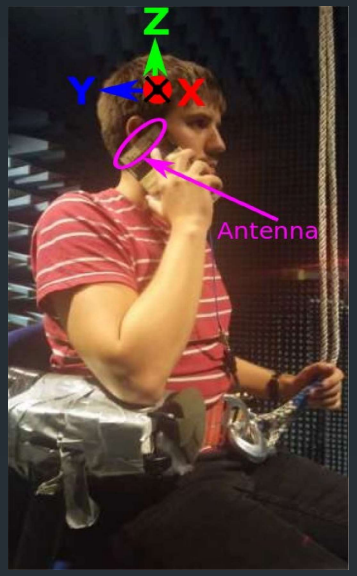
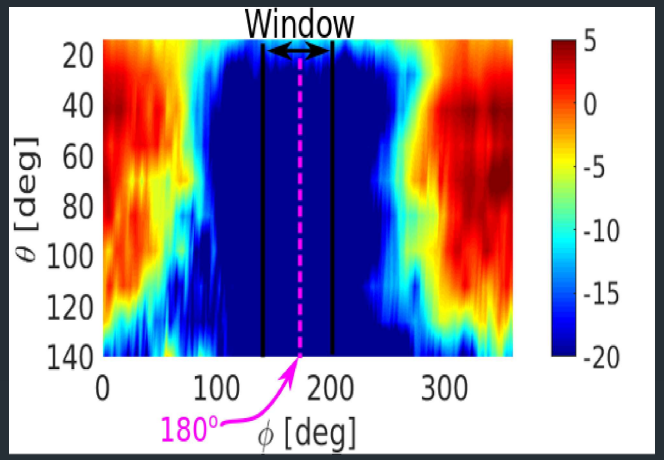


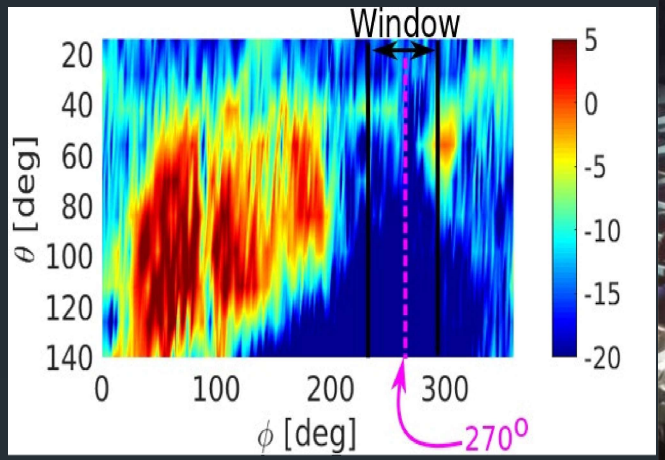
Fig. 6. The histogram of the (a) users' heights and (b) users' weights.

"Statistical Investigation of the User Effects on Mobile Terminal Antennas for 5G Applications,"

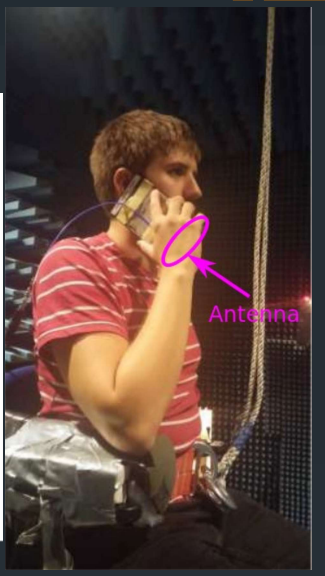


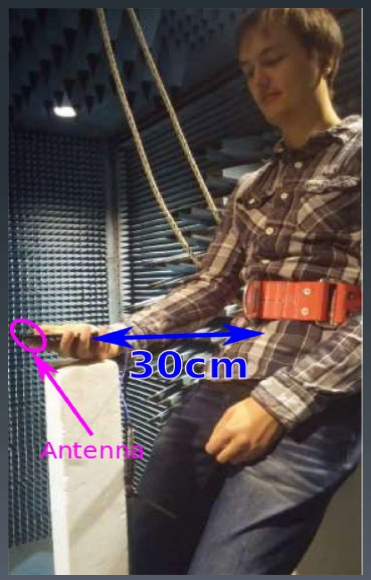


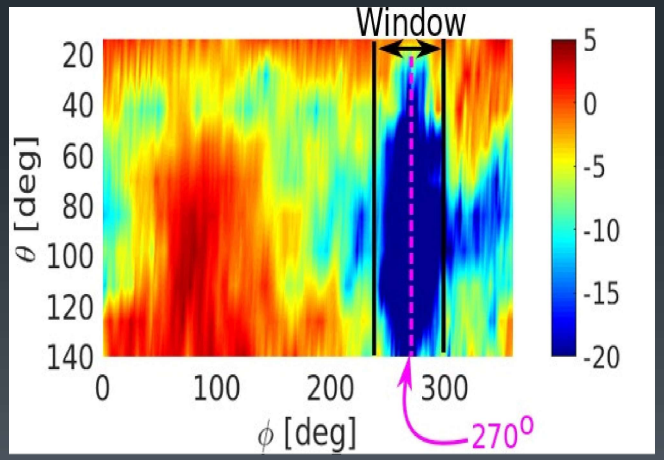
Talk top



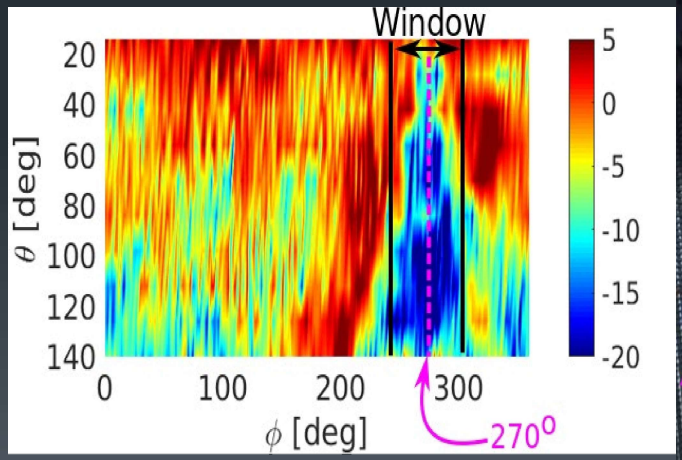
Talk bottom



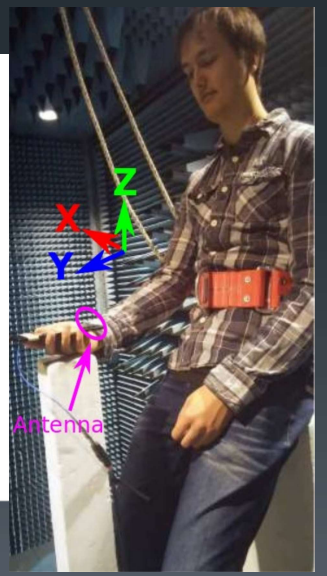




Data top



Data bottom



Channel Characteristics and User Body Effects

28 GHz

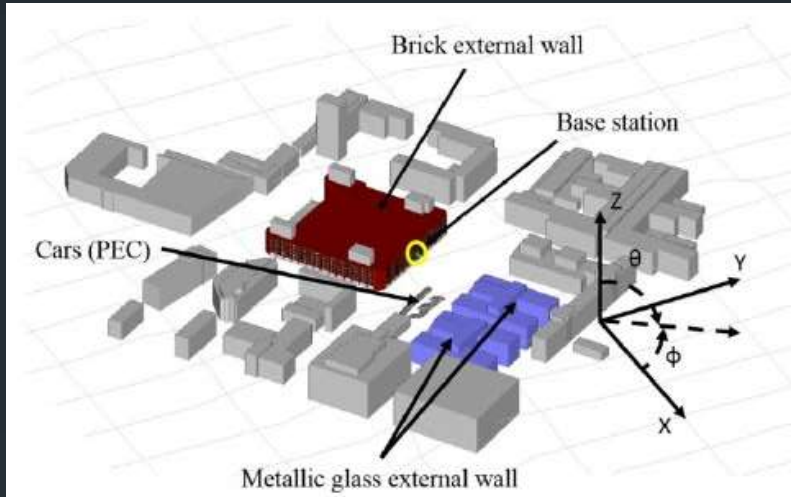
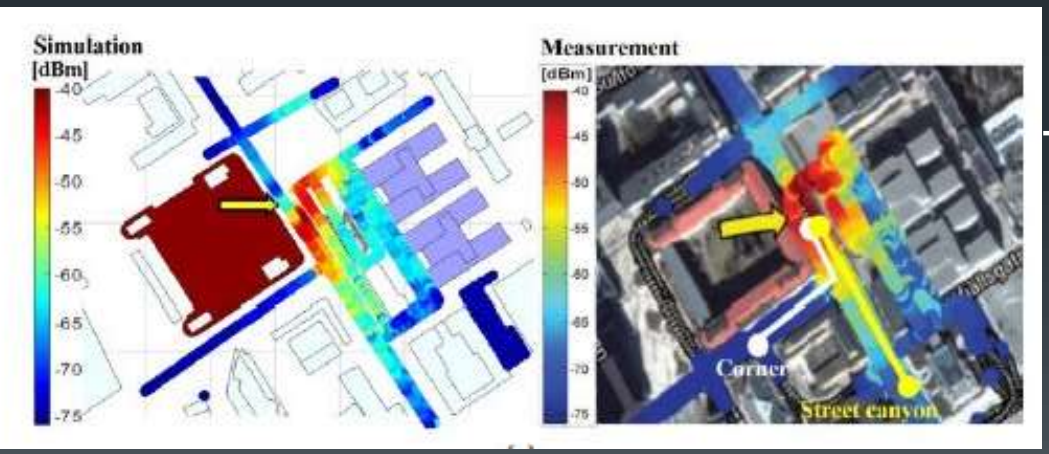


Fig. 2. The 3D model of the study area in ray-tracing simulations.

Free space

Data mode

Talk mode



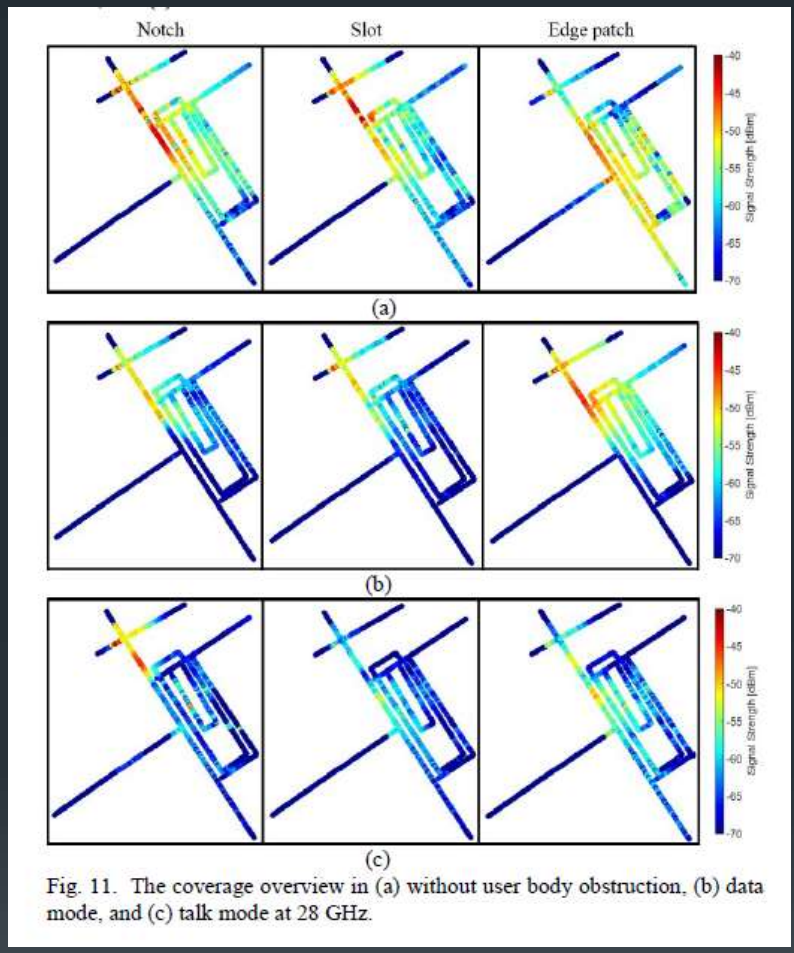
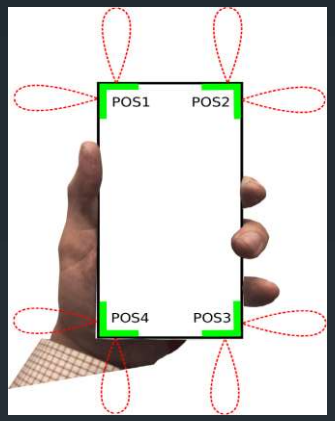


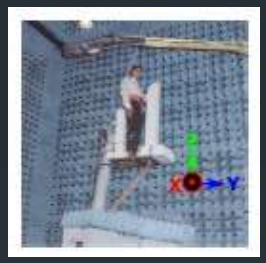
Fig. 11. The coverage overview in (a) without user body obstruction, (b) data mode, and (c) talk mode at 28 GHz.

"Channel Characteristics and User Body Effects in an Outdoor Urban Scenario at 15 and 28 GHz,"

User Shadowing Suppression



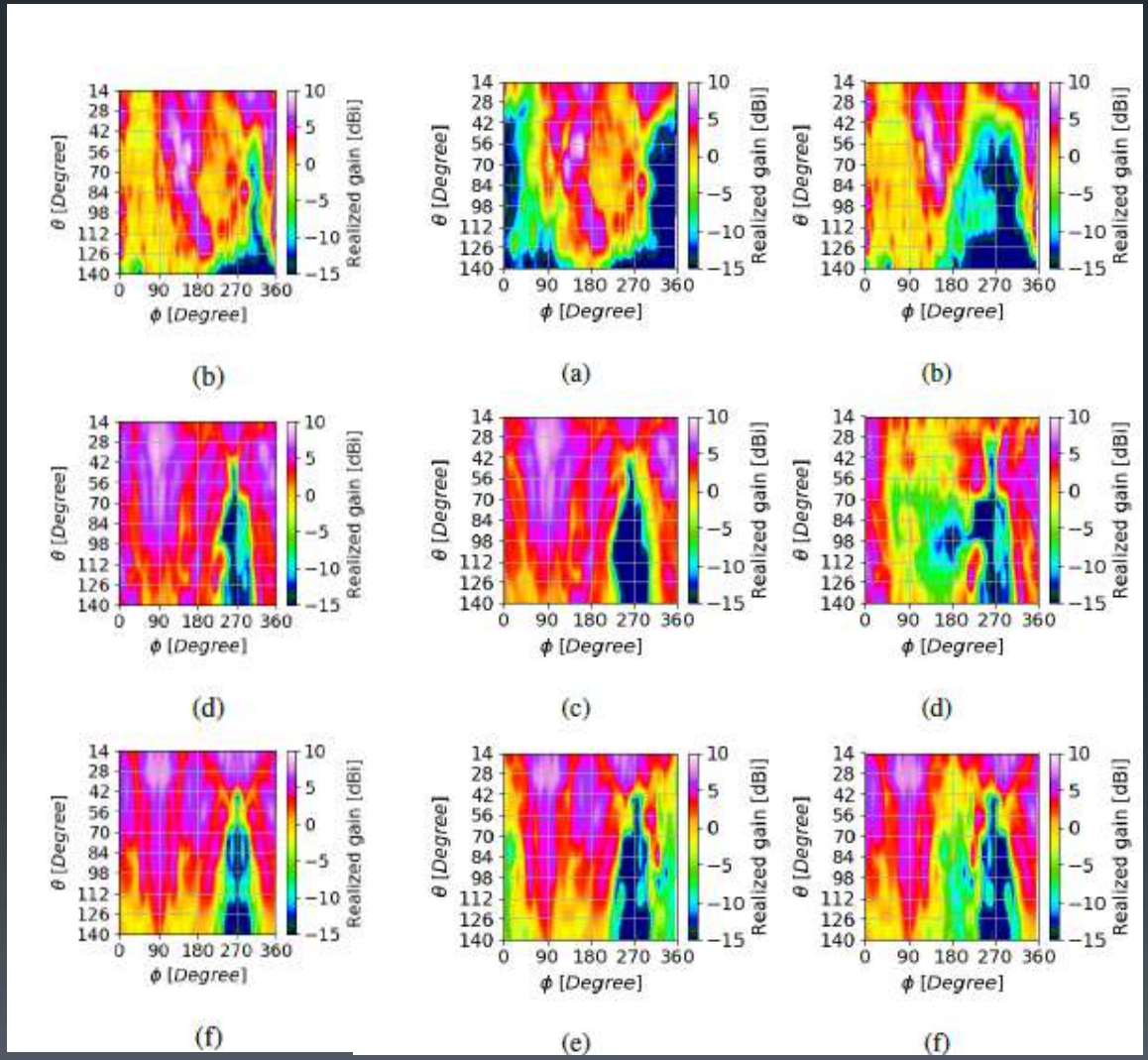
Talk mode



Data mode

Dual-hand mode

POS1+2+3+4 POS1+3 POS2+4



"User Shadowing Suppression for 5G Mm-wave Mobile Terminal Antennas,"

5. Conclusions:

- New challenges in 5G handset antennas

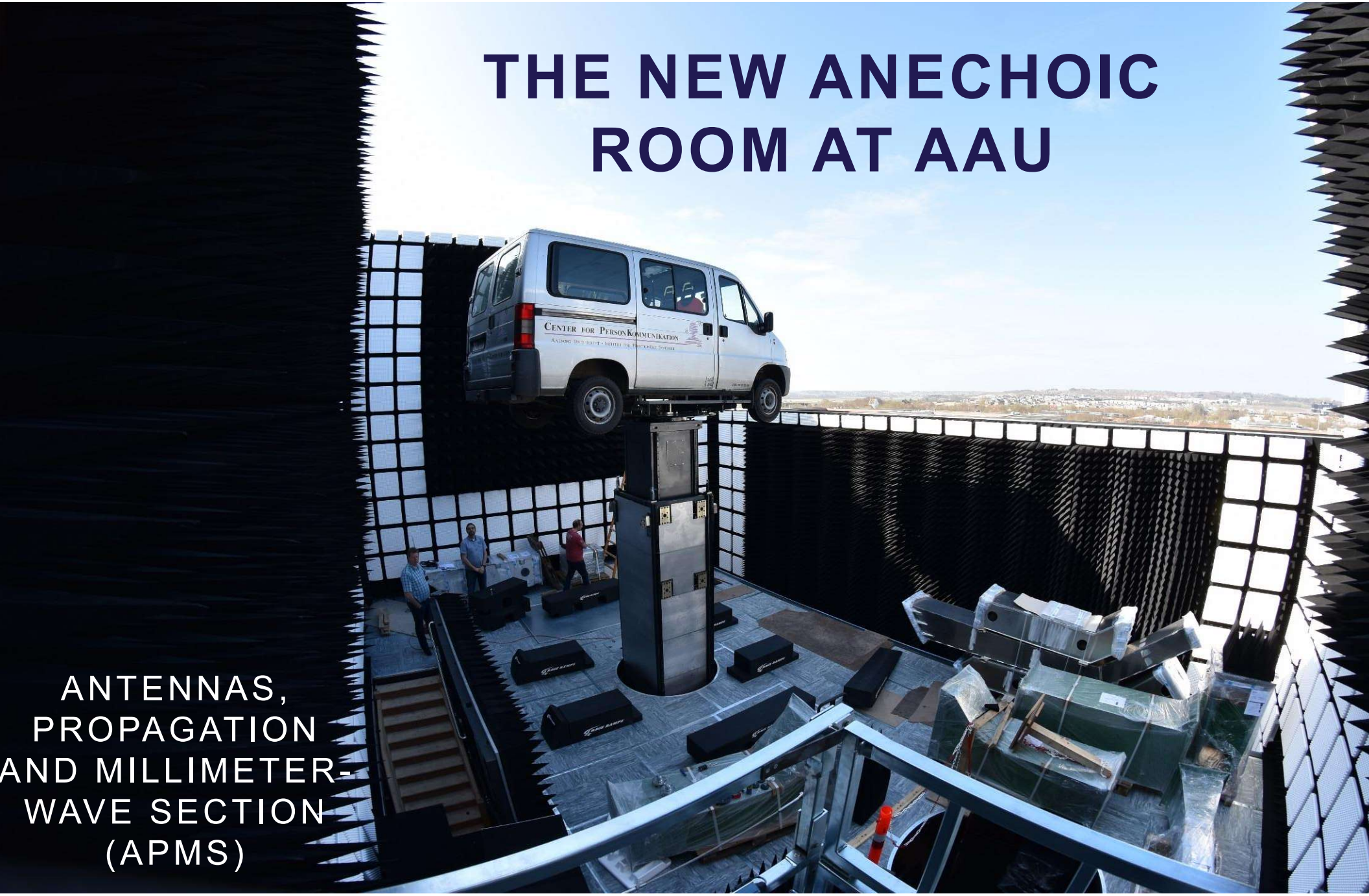
- Design examples

1) Large spatial coverage
2) Wideband
3) Polarization
4) Co-design of sub 3GHz and mmwave antennas
5) Beam steering array with low loss switch

- User effects on mm/cm-wave antenna designs

1) Statistical Investigation
2) Channel Characteristics and User Body Effects
3) User Shadowing Suppression

THE NEW ANECHOIC ROOM AT AAU



ANTENNAS, PROPAGATION AND MILLIMETER-WAVE SECTION (APMS)

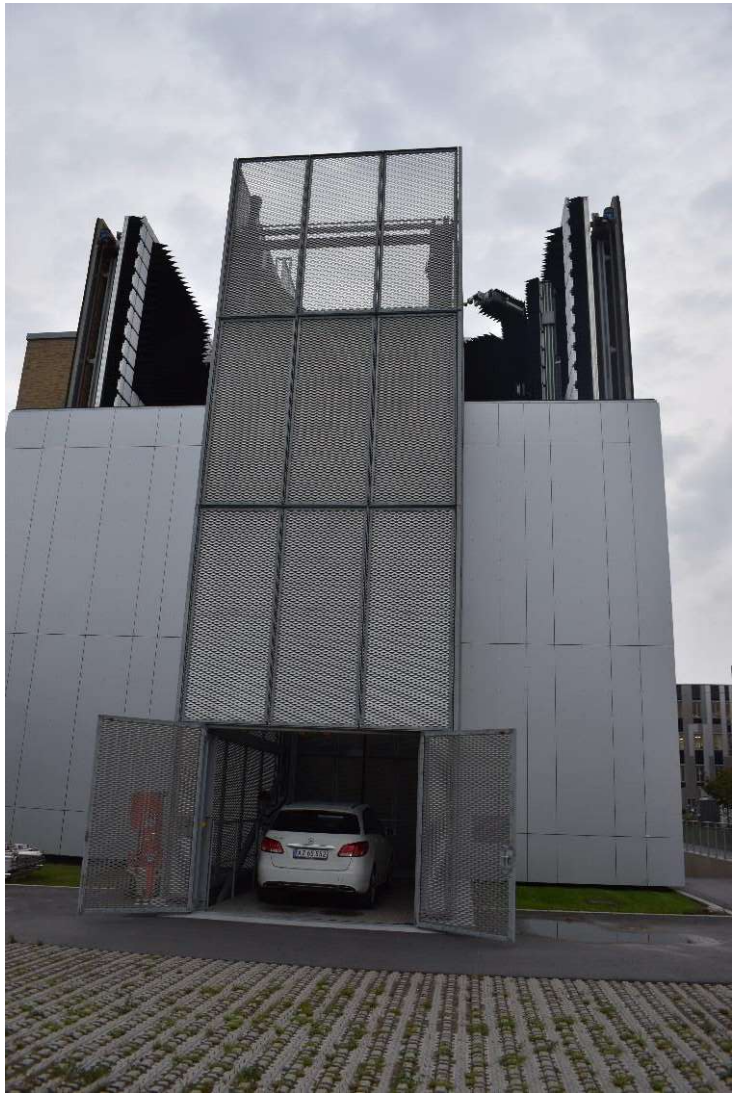
AALBORG UNIVERSITY
DENMARK

The new building

Sliding roof

Sliding wall

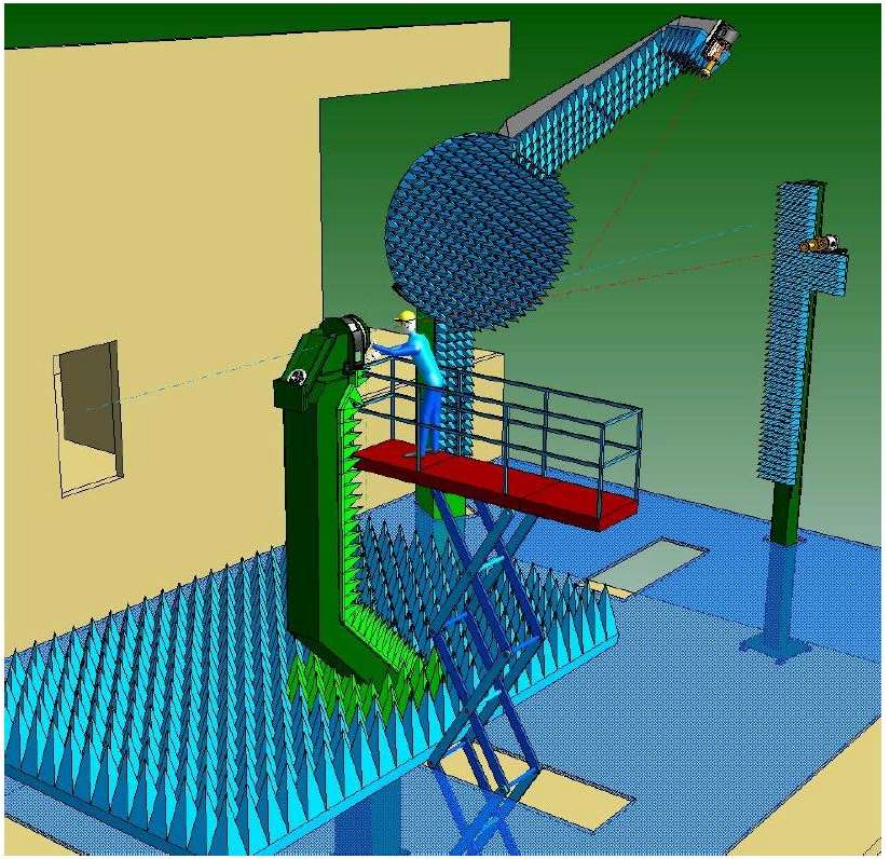
Bulk lift

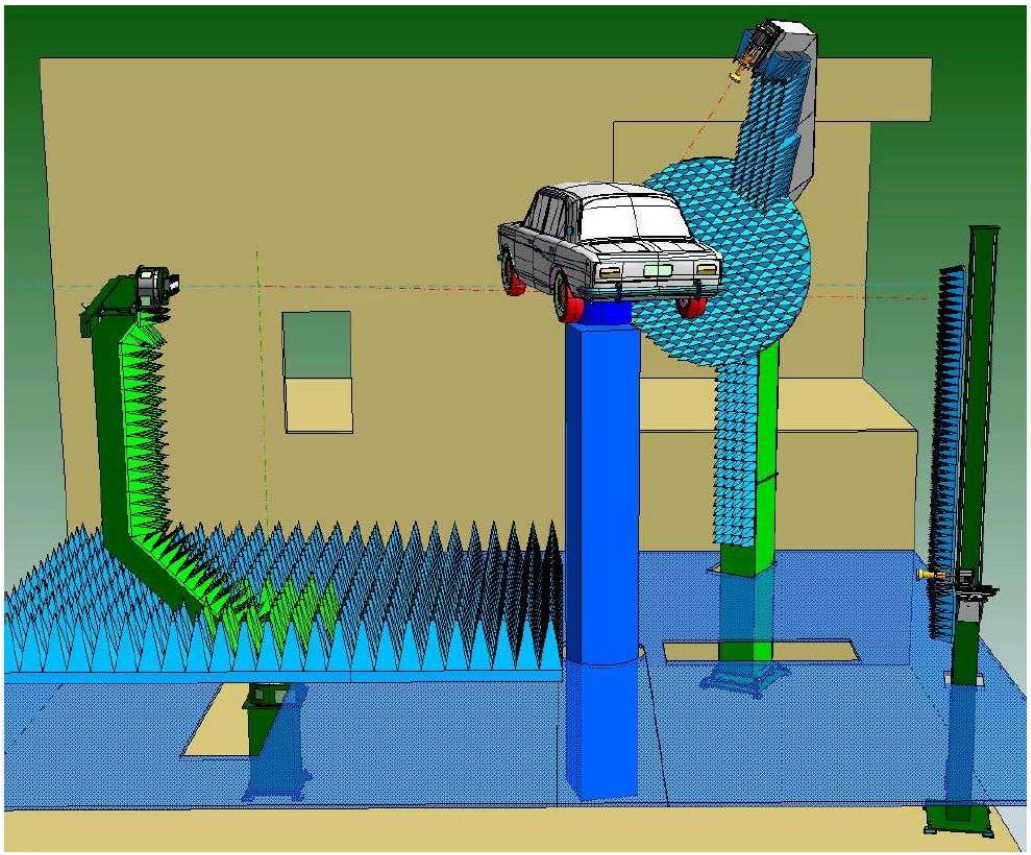


A car into the chamber

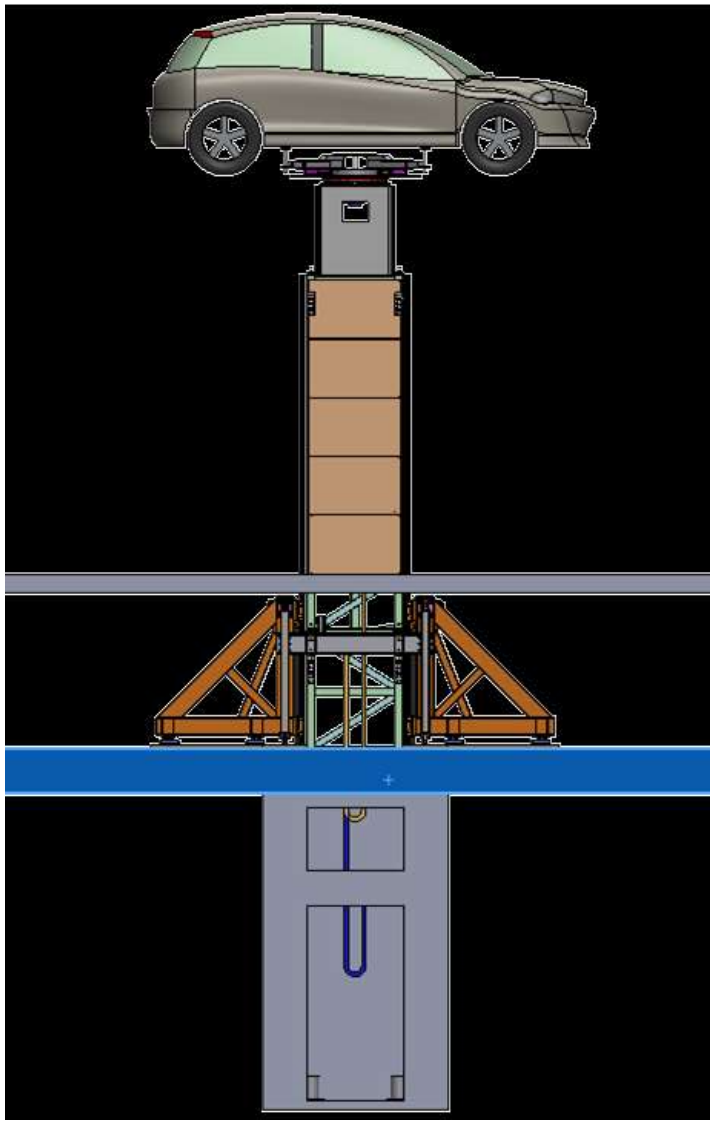
The sliding wall and roof

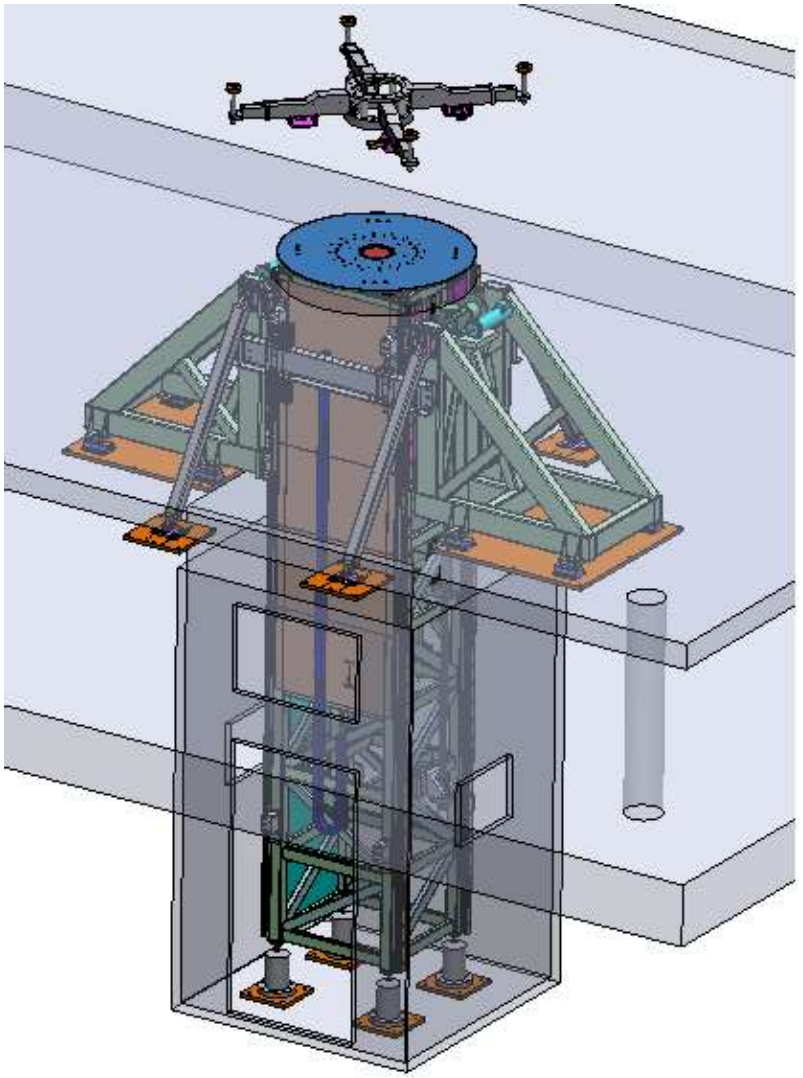
Measurement setup





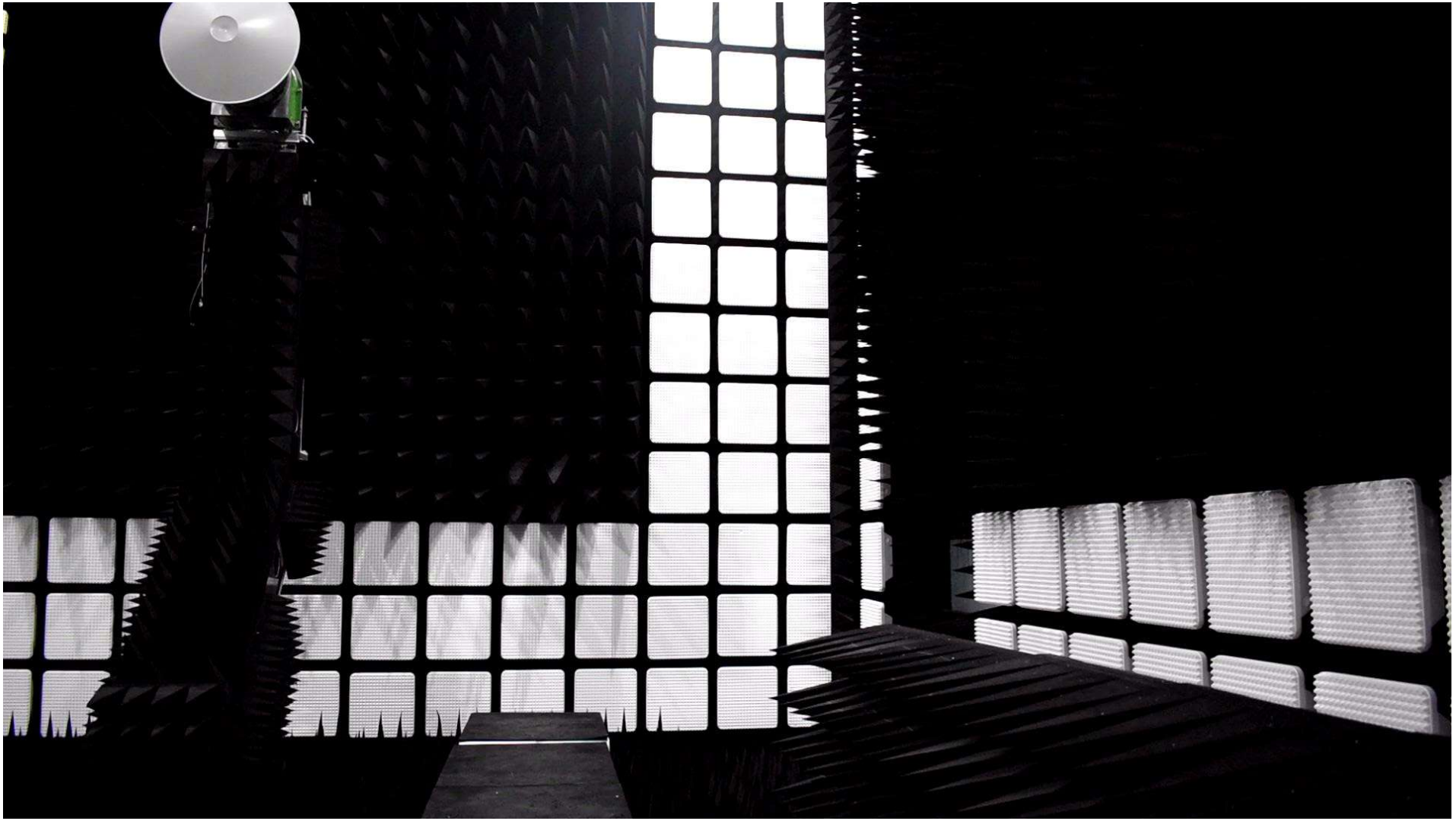
Bulk pedestal





Bulk pedestal

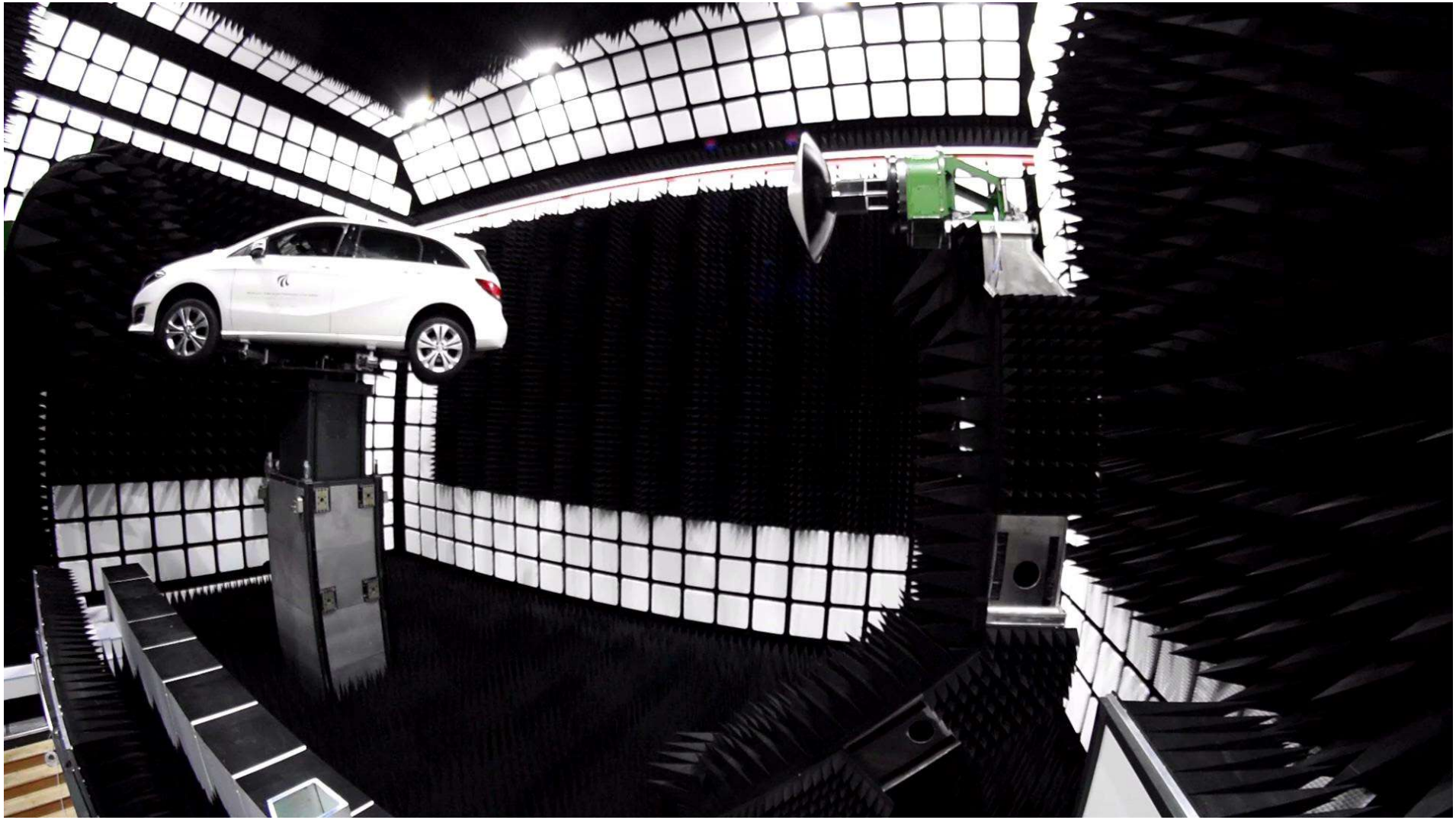
Bridge



Probe hatch

Crane

Sliding roof



Measurement on bulk - a windturbineblade

Measurement on bulk - F16 mission

And the future .. ?